

# Integral Slip Layer for Insulating Tape

## Background

**[0001]** With the use of any form of electrical appliance, there is a need to electrically insulate conductors. Conductors need to be wrapped in a insulating tape to prevent electric discharge. An example of this is shown in Fig. 1. Illustrated here is a coil **13**, comprising a plurality of turns of conductors **14**. Each turn of the conductor **14** consists essentially of a copper bar or wire wrapped with a turn insulation **15**. The turn insulation **15** is prepared preferably from a fibrous sheet or strip which is typically impregnated with a resin. The turn insulation **15** may be not adequate alone to withstand the severe voltage gradients that will be present between the conductor and ground when the coil is installed in a high-voltage generator. Therefore, ground insulation for the coil is provided by wrapping one or more layers of composite mica tape **16** about the turn **14**.

**[0002]** Such a mica-tape **16** comprises a pliable backing sheet **18** of, for example, poly-ethylene glycol terephthalate or glass fabric mat, having a layer of mica flakes **20** bonded to a resin. The tape **16** may be applied half lapped, abutted or in any other suitable manner. Generally, multiple layers of the mica tape **16** are wrapped about the coil with sixteen or more layers generally being used for high voltage coils. The number of layers may be decreased depending on the power of the generator and the effectiveness of the insulator in both its abilities to insulate electrically and conduct heat. To impart better abrasion resistance and to secure a tighter insulation, a wrapping of an outer tape **21** of a tough fibrous material, for example, glass fiber, asbestos or the like may be applied to the coil.

**[0003]** Therefore, what is referred to as insulating tape is actually composed of multiple layers of tape that have different properties. The inner

most layer is referred to as the groundwall insulation. Wrapped around this is the conductive layer. The conductive layer provides a low resistance and doesn't allow voltage to be present between the outer coil surface and the core. As will be discussed below, in order to function properly as a conducting electrode, the conductive layer needs to be in firm contact with both the groundwall insulation and the generator assembly in which the wrapped conductor (coil) is inserted.

**[0004]** As mentioned, the insulating tape is generally impregnated with a resin to improve many of its overall properties. There are many methods of coating materials with epoxy resins and then curing the product. One such method is vacuum pressure impregnation (VPI). This method is used on devices such as stator conductor coils. A mica/glass insulating tape is applied to the coils, then the coils are placed in a vacuum vessel and a vacuum is applied. After a period of time, resin is admitted to impregnate the coils. Pressure is applied to force the resin in and minimize voids, which will affect conductivity. After this is completed, the coils are heated to cure the resin. The resin may contain an accelerator or the tape may have one in it. A variation of this, global VPI involves the process where dry insulated coils are wound, and the then whole stator is vacuum pressure impregnated rather than the individual coils.

**[0005]** The wrapped conductor is then placed into machinery such as a generator. Fig. 2 shows one embodiment of a generator in cross section. The generator comprises a metal armature or rotor **28** having slots **22** therein, containing insulated coils **23**, surrounded by a metal stator **24** having slots **25** therein about the stator circumference at **26**. The stator slots contain insulated coils **27**.

**[0006]** If the conductor is not secure against the generator assembly, electric discharge will result. This adversely affects the performance of the machinery, and also causes cumulative damage to the generator, conductor and insulation tape.

**[0007]** In order to prevent such a discharge, the conductive layer of the insulating tape itself needs to be made of at least two layers, which are

referred to as the outer conductive layer and the inner conductive layer. Note that both of these sub layers may themselves be composed of multiple layer depending on need. The outer layer of conductive tape will be in firm contact with the generator assembly, while the inner conductive layer will be in firm contact with the groundwall insulation. This, however, creates a problem, since the conductor and the generator assembly often have minor movements independent of one another due to such things as heating and vibration. This is referred to as a difference of movement. If the outer conductive layer of the insulating tape is in firm contact with the generator assembly, and the conductor moves independently of the assembly, stresses are created on the insulating tape.

**[0008]** These stresses cause the tape to tear, ruining the insulation around the conductor coil. To prevent this, machinery is run at below desired level to prevent movements due to vibration and temperature.

**[0009]** An alternate solution is to provide a slip layer in the insulating tape. This slip layer is sandwiched between an inner conductive layer, which is in contact with the conductor, and the outer conductive layer, which is in contact with the generator assembly. The slip layer consists of a mica-filled tape that is interwoven with a conductive tape, as shown in Fig. 3. The mica-filled slip layer consist primarily of large mica flakes, generally larger than those used in other insulating layers. Therefore they are not well bonded together and can slip relative to each other. A conductor **13** is wrapped with a groundwall insulation layer **43** and then a inner conductive layer **44** followed by a mica-filled tape **41** that has a conductive interweave **42** woven horizontally along one side. This slip layer allows for a minor difference of movement between the inner **44** and outer **46** conductive layers, without causing any tears or damage to the tape.

**[0010]** This solution, however, is not with out its own problems. One concern is that the slip layer, because of being a mica-filled tape, is extremely delicate. This means that the slip layer, and often the entire insulating layer, has to be wound around the conductor by hand, rather than using more efficient machinery. Because the mica-filled tape has large flakes, it is delicate and there for is more susceptible to handling damage. Also, the

amount of slip that the slip layer allows for is only moderate. Therefore the difference of movement between the conductor and generator assembly cannot be too significant. Further, the mica-filled tape is on average 11.5 mils thick (0.3 mm). Since the assembly needs to produce an overlap of the tape, this increases the overall insulating tape thickness to 25 mils (0.65 mm) per side of the conductor coil. This added thickness not only adds to the overall size of related machinery, but also reduces efficiency in properties such as thermal conductivity.

**[0011]** The mica-filled tape, however, has not been able to be replaced because of the nature of the mica-flakes. They provide the needed dielectric strength. They are also porous to the resins used in impregnating the insulating tape. Without proper porosity, the inner conductive layer will not saturate properly, thus ruining the properties of the insulating tape.

**[0012]** What is needed is a slip layer that is thinner, more resilient and that allows a greater slip tolerance, while maintaining or improving upon the dielectric properties and porosity of the prior art.

## Summary of the Invention

**[0013]** The present invention provides for a non-stick material coated glass slip layer for use in insulating tapes for electrical conductors. A conductive glass tape is interwoven with a non-stick material coated glass tape to form the slip layer of the present invention. The slip layer is sandwiched between an inner conductive layer that is in contact with an electrical conductor, and an outer conductive layer that is in contact with machinery, such as a generator. The slip layer allows for a difference of movement between the inner conductive layer and the outer conductive layer without damage to the insulating tape.

**[0014]** In one embodiment the slip layer is between 2-6 mils (0.05–0.15 mm) thick without overlap.

**[0015]** In a particular embodiment the insulating tapes are impregnated with a resin after being wound around the electrical conductor.

- [0016]** In one embodiment the ratio of the conductive interweave to the slip layer is between 1:1 and 1:8 by surface area.
- [0017]** In another embodiment, the conductive interweave has a resistance of approximately 200 ohms per square.
- [0018]** In a particular embodiment the slip layer and the conductive interweave are machine wound around the electrical conductor.
- [0019]** In a further particular embodiment the difference of movement is up to about 0.5 inches (13 mm).

## Brief Description of the Drawing

- [0020]** Figure 1 illustrates insulative wrappings around a conductor.
- [0021]** Figure 2 shows a cross sectional view of a generator where insulated conductors are used.
- [0022]** Figure 3 shows a mica-tape slip layer of the prior art.
- [0023]** Figure 4 illustrates one example of how the slip layer of the present invention may be wound.
- [0024]** Figure 5 illustrates an electrical conductor after being wrapped by a slip layer of the present invention.

## Detailed Description of the Invention

- [0025]** In one embodiment, the present invention provides insulating tapes for insulating an electrical conductor. The tapes comprise a groundwall layer, an inner conductive layer, an outer conductive layer, and a slip layer located between the two conductive layers. The slip layer itself comprises non-stick material coated porous glass tape. The slip layer allows for a difference of movement between the inner conductive layer and the outer conductive layer without damage to the insulating tape. Interwoven with the slip layers is a conductive interweave. The slip layer is wrapped around the electrical conductor in an overlapping manner that allows the conductive

interweave to maintain contact between the inner conductive layer and the outer conductive layer. Also, the porosity of the slip layer is sufficient to allow an impregnation of a resin through the slip layer to the inner conductive layer

**[0026]** As used herein, the term non-stick material refers to all non-stick materials that may be coated on a glass surface in accordance with the present invention. Example of this include, but are not limited to, tetrafluoroethylene (TFE and PTFE), which is also referred to as Teflon®, chlorotrifluoroethylene (CTFE), polyvinylidene fluoride (PVF<sub>2</sub>), perfluoroalkoxy (PFA), polyethylene, unplasticized polyvinyl chlorides (Saran), and acrylonitrile butadiene styrene (ABS).

**[0027]** In one embodiment the slip layer is between 2-6 mils (0.05–0.15 mm) without overlap. This refers to the general thickness of the Non-stick material coated glass tape itself. Once wrapped around the electrical conductor, the slip layer will generally overlap with itself or the interwoven conductive layer. In a particular embodiment the slip layer and the conductive interweave are wound around the electrical conductor in a half lap manner. Depending on the orientation of how the slip layer is wound, this may produce a vertical striping pattern somewhat perpendicular to the axis of the electrical conductor.

**[0028]** In a particular embodiment the insulating tapes are impregnated with a resin after being wound around the electrical conductor.

**[0029]** In one embodiment the ratio of the conductive interweave to the slip layer is between 1:1 and 1:8 by surface area. In another particular embodiment the ratio of the conductive interweave to the slip layer is between 1:2 and 1:4 by surface area.

**[0030]** In a further embodiment, the slip layer is approximately 1.18 inches (30 mm) wide, and in a related embodiment, the conductive interweave is approximately 0.59 inches (15 mm) wide.

**[0031]** In another embodiment, the conductive interweave has a resistance of between 10 and 10,000 ohms per square. In a particular embodiment the resistance is approximately 200 ohms per square.

**[0032]** In a particular embodiment the slip layer and the conductive interweave are machine wound around the electrical conductor. This is a great improvement over the prior art, where the slip layer is hand wound around the electrical conductor.

**[0033]** In a further particular embodiment the difference of movement is up to about 0.5 inches (13 mm). This is the approximate maximum movement that a conductor is likely to move in relation to an abutted machine assembly. Other applications may require a greater difference of movement, to which the present invention is equally suited to achieve. In still another particular embodiment the insulating tape maintains physical properties at temperatures of 155 °C.

**[0034]** In another embodiment, the present invention provides for a slip layer with conductive interweave for use in insulating tape on electrical conductors that comprises non-stick material coated porous glass tape and glass conductive tape. The non-stick material tape and the conductive tape are interwoven in a manner such that the conductive tape transverses the slip layer such that the conductive tape is exposed on both sides of the slip layer. The ratio of the conductive tape to the non-stick material glass tape from 1:1 to 1:8 by surface area of the slip layer, and the porosity of the non-stick material tape is sufficient to allow an impregnation of a resin through the slip layer.

**[0035]** In still another embodiment, the present invention provides for a method for manufacturing an insulating tape with an integral slip layer for wrapping of an electrical conductor. This method comprises wrapping an inner conductive layer of glass tape around the electrical conductor and then wrapping non-stick material coated porous glass tape interwoven with a conductive interweave glass tape around the electrical conductor over the inner conductive layer, wherein the slip layer is formed. Then wrapping an outer conductive layer of glass tape around the electrical conductor over the slip layer. To this, a resin is impregnated all the way to the inner conductive layer through the Non-stick material coated porous glass tape, and is then cured. In this method the slip layer is wrapped around the electrical conductor in an overlapping manner that allows the conductive interweave to maintain

contact between the inner conductive layer and the outer conductive layer. The slip layers allows for a difference of movement between the inner conductive layer and the outer conductive layer without damage to the insulating tape.

**[0036]** In a particular embodiment the non-stick material coated porous glass tape and the conductive glass tape are machine wound on the electrical conductor

**[0037]** Fig. 4 illustrates a simplified embodiment of the present invention. The slip layer is composed of non-stick material coated porous glass tape **40** interwoven with a conductive interweave glass tape **42**. The slip layer allows a difference of movement between the inner conductive layer **44**, which is in contact with an electrical conductor (not shown), and an outer conductive layer **46**, which is in contact with machine assembly (not shown). In this figure, the various tapes and layers are shown spaced apart for clarity. In actuality, however, little or no space between the tapes and layer would be present. The type of wrapping shown in this figure exemplifies an typical half lap wrapping. Other types of wrapping will be known to one of ordinary skill in the art. In this example, the Non-stick material coated porous glass tape is about twice as wide as the conductive interweave glass tape. Also, the Non-stick material coated porous glass tape is wound twice for every wind of the interweave glass tape. Variations in this configuration will be appreciated by one of ordinary skill in the art. A goal in the wrapping is to maximize the amount of slip protection that the non-stick material coated tape provides, while maintaining sufficient electrical conduct between the inner and outer conductive layers through the conductive interweave. This includes allowing for environmental conditions, such as operating temperatures of 155°C.

**[0038]** Therefore, the amount of surface area of the slip layer that is the conductive interweave maybe anywhere from approximately 12% to 50%, with a particular embodiment being approximately 25%. Fig. 5 illustrates a slip layer wound about an electrical conductor in this manner. The half lap method produces a somewhat vertical striping of the conductive interweave **42** between the non-stick material coated glass **40**. The outer conductive layer would then be added to the slip layer to complete the insulating tape.



**[0039]** This slip layer is sandwiched between an inner conductive layer, which is in contact with the conductor, and the outer conductive layer, which is in contact with the machinery, such as generator assembly or generator part. Both conductive layers need to be in firm contact with the conductor and the assembly respectively, otherwise efficiency will be lost and damaging discharges will occur. Since the electrical conductors heat at a different rate than the surrounding assembly, there will be movement due to expansion. Since the conductors can be several meters long, thermal expansion will cause a difference of movement between the inner and outer conductive layers. Other factors, such as vibrations, may also contribute to the difference of movement. This difference of movement is often 0.25 inches (6.5 mm) and up to 0.5 inches (13 mm) or more. The slip layer allows for this movement without tearing, while the conductive interweave maintains electrical conduct between the two layers.

**[0040]** The non-stick material may be coated on the porous glass by methods known in the art, such as Teflon® spray coating.

**[0041]** Though particular embodiments have described the use of a single slip layer in the insulating tape, other applications may require multiple slip layers to be used. The present invention is not bound by the use of single slip layer. Multiple slip layers, either stacked or interspersed, are within the scope of the present invention.

**[0042]** The term glass as used herein refers to any type of glass-like fiber used in insulating tape, including such materials as poly-ethylene glycol terephthalate and asbestos. Though high thermal glass weaves are a common embodiments, the present invention may also be used with glass fleeces, and polyesters such as Dacron™.

**[0043]** While specific embodiments of the invention have been described in detail, it will be appreciated by those skilled in the art that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. Accordingly, the particular arrangements disclosed are meant to be illustrative only and not limiting as to

the scope of the inventions which, is to be given the full breadth of the claims appended and any and all equivalents thereof.